Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

AN UNUSUAL FORM OF VOLCANIC EJECTA[1]

WALLACE E. PRATT
Chief Division of Mines, Bureau of Science, Manila, Philippine Islands

In the course of a study of the eruption of Taal Volcano, in southwestern Luzon, Philippine Islands, during the month of February, 1911, I noted the presence of small concretion-like bodies in the finest-grained portion of the blanket of fragmental ejecta which the eruption spread over the surrounding country. It will be recalled that the eruption in question was characterized, by the expulsion of great volumes of water-vapor, charged with ash or sand, together with a small proportion of coarser fragmental material. The eruption destroyed completely a dozen small villages, with attendant damage to crops and live stock, and killed 1,335 people. A thin layer of mud and dust was spread over an area of about 1,000 square kilometers, extending principally to the north and west of the crater. I commented upon the presence of the spherical bodies in the ash-fall at the time as follows:

> An interesting feature of the fall of the ejecta is the formation of drops or balls of mud. These were observed most abundantly on the island itself, but were seen at Talisay and Bañadero also. They range in size from large shot to hazelnuts, and when broken sometimes show concentric markings. Apparently they fell late during the activity, being found just below the surface of the deposit. These mud balls cannot be classed as lapilli in the strict sense of that term, since they are built up, probably through the condensation of steam into drops of water. The accompanying vertical section of the fall of mud or ash [text Fig. 2] was taken on the southwest slope of the volcano.[2]

Text Fig. 2, referred to in the quotation, is reproduced herewith as text Fig. 1.

Taal Volcano forms an island near the center of a lake from 15 to 20 kilometers in diameter. Thus the mud balls, which were found both on the slopes of the volcano and at the villages of Talisay

[1] Published by permission of the Director, Bureau of Science, Manila, Philippine Islands.

[2] Wallace E. Pratt, *Phil. Jour. Sci.*, Sec. A (1911), VI, 71.

and Bañadero on the margin of the lake, from 6 to 8 kilometers distant from the crater, must have been widely distributed; nevertheless, at the time I was inclined to attribute their formation to accidental, rather than to common, conditions of explosive volcanism. The literature accessible to me revealed little evidence that ejecta of this character had been observed generally, although the following description by Edward Otis Hovey of "drops of mud," which he encountered after the eruptions on Martinique in 1902, shows that similar phenomena have been noted:

> In addition to the showers of dry dust and ashes, there fell during the eruption an immense amount of liquid mud which had been formed within the eruption cloud through the condensation of its moisture. This mud formed a tenacious coating over everything with which it came in contact. That drops of mud, too, formed in the air and fell as a feature of the eruption is proved by the condition of the walls the of houses in Precheur, on which I found flattened spheroids of dried mud which could have formed only in the manner indicated. These flecks of mud were two, four, and even six inches across, where two or more had coalesced. They occurred mostly on the northern and eastern walls of the houses. The testimony of the people as to the occurrence of rain during the great eruption is conflicting, but the evidence of the coating and these drops of mud proves that much aerial condensation of steam accompanied these outbursts.[1]

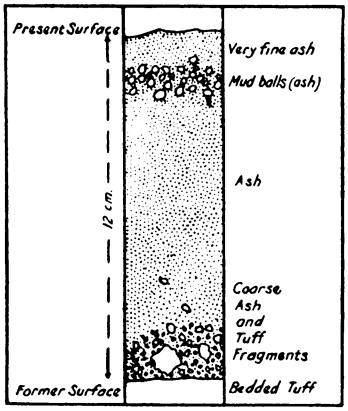

FIG. 1.—Section of ash which fell on the southwestern slope of Taal Volcano in January, 1911, showing balls of dried mud near top of layer.

More recently I have come upon evidence which leads me to the belief that the formation of mud balls has been rather characteristic of that type of volcanic activity which results in the explosive eruption of great clouds of dust-laden steam, at least where atmospheric conditions similar to those on the island of Luzon prevail. In the examination of samples of strata pierced in drilling for artesian water at the towns of Bauan and Taal, distant 25 and 15 kilometers, respectively, from the crater of Taal Volcano, abundant

[1] Edward Otis Hovey, *Am. Jour. Sci.*, XIV (1902), 343.

spheroidal and ellipsoidal inclusions were found which are indistinguishable from the mud balls of the last eruption of Taal. These ejecta may have come from Taal itself, or from some other of the numerous small craters which are known to have existed in southwestern Luzon formerly. The wells were drilled by the Bureau of Public Works with standard drilling rigs, and the samples

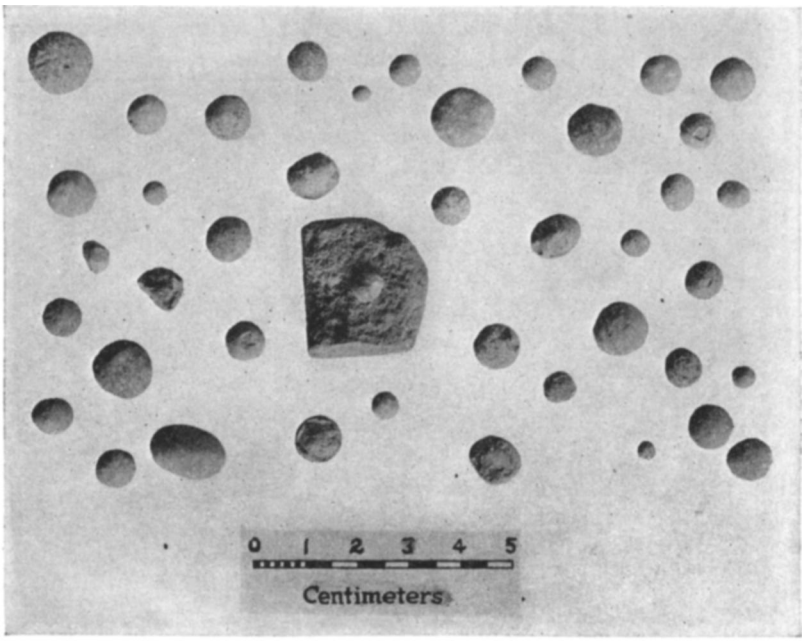

FIG. 2.—Photograph of balls of dried mud which fell with the fine tuff portion of the ejecta of Taal Volcano, in the eruption of 1911.

studied were submitted by the drillers. The balls of dried mud came from depths of from 100 to 150 meters in very loosely consolidated, silt-like volcanic tuff, fragments of which had evidently caved into the well and had been brought to the surface by the sand pump or bailer. Some of the balls were broken, but many were intact in spite of the disintegrating effect which the rushing action of the water into the bailer must have caused.

The size and appearance of the balls are well shown in the accompanying photograph (Fig. 2). One specimen still imbedded

in the tuff appears near the center of the photograph. The broken surfaces display clearly the concentric structure which is characteristic of these bodies. The balls can be disintegrated between the fingers when wetted, and the individual particles prove to be like dust in size. That these aggregates have not resulted from solution processes nor from dynamism is evidenced by the facts that they do not contain calcium carbonate nor any other extraneous cementing agent, and that the beds in which they occur have certainly not experienced metamorphism. The theory which Dr. Hovey advanced to explain the presence of "drops of mud" in the ejecta from Mont Pelée accounts satisfactorily for the similar, although apparently smaller, balls of dried mud in the loose tuffs of southwestern Luzon.

W. H. Brown, botanist, Bureau of Science, has submitted to me several hundred balls of dried mud which he found included "in the upper part of a thick bed of volcanic tuff" on the slopes of Mount Maquiling, an extinct volcano about 20 kilometers northwest of Taal. He had been engaged in a study of the flora of Mount Maquiling and had encountered these balls in the course of a soil survey. They are precisely like those already described in shape and structure, but many of them are larger and they have a brownish-yellow color, whereas the Taal products are light gray in color. They consist of the same material as the inclosing bed—clayey, fine-grained tuff. The balls from Maquiling attain a diameter in rare specimens of as much as 4 centimeters, thus being comparable in size with the drops of mud observed by Dr. Hovey, and are so hard that they can be broken only with difficulty between the fingers. The appearance of a face in the tuff bed containing these balls is shown in Fig. 3. The concentric structure of the balls is again revealed in this photograph.

Recently, also, I have encountered well-preserved balls inclosed in clayey tuff on Bondoc Peninsula, Tayabas Province, and near the Santa Lutgarda iron mine at Angat, Bulacan Province, widely separated parts of Luzon. The tuff beds in these localities are of greater age than the recent tuffs in the Taal volcanic region, dating back, probably, to the late Miocene. The tuff is slightly indurated, but the balls have retained their form and display

clearly the characteristics already recorded in describing the ejecta from Taal. I am confident that they originated in the same manner in each case.

The suggestion arises, in view of the foregoing observations, that the condensation of mud into drops or balls must be a rather common feature of volcanic eruptions which throw out great clouds of water-vapor and fine sand or dust. The product may be

FIG. 3.—Photograph showing close view of a face in a bed of clayey tuff containing "mud balls"; slopes of Mount Maquiling, southwestern Luzon. About one-third natural size.

described, perhaps, as a volcanic hailstone. Undoubtedly, the contour of such bodies is often destroyed by the impact of the fall to the ground surface. Probably only where the drops have had opportunity to dry out somewhat before reaching the earth and where they strike in soft, unconsolidated beds of recently fallen tuff, is their form preserved under subaerial conditions. It would appear to be equally remarkable that they should retain their form upon falling into water. Yet it is beyond question that the tuff series into which the wells at Bauan and Taal penetrated is in great part water-laid, and it is to be presumed that the mud

balls encountered in the wells at these towns fell into the sea originally.

Unless conditions peculiar to the tropics, such as high temperature and, perhaps, excessive humidity, are essential factors in the phenomena which have been described, it would appear that mud balls should have been formed in the eruption cloud from Katmai Volcano in Alaska and in the recent eruptions of Mount Lassen in California. So far as I have observed, none of the published accounts of the eruptions of these volcanoes have mentioned ejecta of this character.